CLAIMS

We Claim:

1. An apparatus for fabricating a fiber grating structure comprising:

an optical fiber having a central longitudinal axis; and

fabrication means for imposing refractive index modulation along the central longitudinal axis of said optical fiber in one of a first and second configuration, wherein in said first configuration said optical fiber is formed into a chiral structure having a first pitch and a period, wherein said first pitch is twice said period, and wherein in said second configuration said optical fiber is formed into a chiral structure having a second pitch and a period, wherein said second pitch is substantially equal to said period.

2. The fiber grating fabrication apparatus of claim 1, wherein said fabrication means comprises:

first process means for imposing said refractive index modulation in said first configuration as a double helical pattern comprising a first helix pattern having a predetermined pitch and a second helix pattern of said predetermined pitch along said longitudinal axis of said optical fiber, wherein said second helix is arranged one half of said predetermined pitch forward of said first helix along said central longitudinal axis.

3. The fiber grating fabrication apparatus of claim 1, wherein said fabrication means comprises:

second process means for imposing said refractive index modulation in said second configuration as a single helical pattern having said second pitch along said longitudinal axis of said optical fiber.

4. The fiber grating fabrication apparatus of claim 1, wherein said optical fiber is selected from a group consisting of: an optical fiber core and an optical fiber core enclosed by at least one cladding layer.

5. The fiber grating fabrication apparatus of claim 1, wherein said optical fiber comprises a first end and a second end, and wherein said fabrication means comprises:

a first process stage that retains said first end of said optical fiber;

a second process stage that retains said second end of said optical fiber; and

a third process stage, positioned between said first and said second process stages, that imposes said refractive index modulation in one of said first and second configurations on said optical fiber, between said first end and said second end, to form said optical fiber into a chiral fiber grating.

6. The fiber grating fabrication apparatus of claim 5, further comprising:

vibration control means for restricting lateral vibration of said optical fiber.

7. The fiber grating fabrication apparatus of claim 6, wherein said vibration control means comprises at least one aperture, sized to receive and retain said optical fiber while restricting lateral movement thereof, defined in at least one of said first, second, and third process stages.

8. The fiber grating fabrication apparatus of claim 6, wherein said vibration control means comprises at least one member each having an aperture, sized to receive and retain said optical fiber while restricting lateral movement thereof, said at least one member being positioned between at least two of said first, second, and third process stages.

9. The fiber grating fabrication apparatus of claim 5, wherein said second process stage further comprises a tensioning unit for providing constant tension to said second end of said fiber.

10. The fiber grating fabrication apparatus of claim 5, wherein said optical fiber is selected from a group consisting of:

an optical fiber core having a non-circular cross-section with 180 degree cross-sectional symmetry;

an optical fiber core having a non-circular cross-section with 180 degree cross-sectional symmetry enclosed in and in contact with a hollow cladding cylinder having an inner surface having filling material disposed in an empty area between said optical fiber core and said inner surface of said cladding cylinder, fiber core being composed of a first dielectric material and said filling material being composed from a second dielectric material, wherein said first and second dielectric materials are of different optical properties;

an optical fiber core having a single groove inscribed in its outer surface along said central longitudinal axis;

an optical fiber core having at least one pair of opposed grooves inscribed in its outer surface along said central longitudinal axis;

an optical fiber core composed of said first dielectric material having a single groove inscribed in its outer surface along said central longitudinal axis, wherein said groove is filled with said second dielectric material having optical properties that are different from said first dielectric material;

an optical fiber core composed of said first dielectric material having a pair of opposed grooves inscribed in its outer surface along said central longitudinal axis, wherein said pair of grooves are filled with said second

dielectric material having optical properties that are different from said first dielectric material;

an optical fiber core composed of said first dielectric material having an elongated member, of a smaller diameter than said optical fiber core, composed of said second dielectric material positioned on its outer surface along said central longitudinal axis;

an optical fiber core composed of said first dielectric material having a pair of opposed elongated members, of a smaller diameter than said optical fiber core, composed of said second dielectric material positioned on its outer surface along said central longitudinal axis;

an optical fiber core comprising, clockwise, a first elongated quarter-cylindrical portion composed of said first dielectric material, a second elongated quarter-cylindrical portion composed of said second dielectric material, in contact with said first portion, a third elongated quarter-cylindrical portion composed of said first dielectric material in contact with said second portion, and a fourth elongated quarter-cylindrical portion composed of said second dielectric material in contact with said third and said first portions, said second dielectric material having different optical properties from said first dielectric material; and

an optical fiber core having a first elongated half-cylindrical portion composed of said first dielectric material and a second elongated half-cylindrical portion composed of a second dielectric material, said second dielectric material having different optical properties from said first dielectric material, and said first and second portions having their flat surfaces in contact with one another.

11. The fiber grating fabrication apparatus of claim 5, wherein one of said first and second process stages comprises:

first twisting means for twisting in a first direction at a first twisting speed and acceleration, during operation of said third process stage, said optical fiber by one of said first and said second ends while the other of said first and second ends is retained by the other of said first and second process stages.

12. The fiber grating fabrication apparatus of claim 11, wherein the other of said first and second process stages comprises:

second twisting means for twisting in a second direction at a second twisting speed and acceleration, during operation of said third process stage, said optical fiber by the other said first and said second ends while said one of said first and second ends is twisted by said first twisting means in said first direction.

13. The fiber grating fabrication apparatus of claim 12, wherein said first direction is radially opposite to said second direction.

14. The fiber grating fabrication apparatus of claim 12, wherein said first twisting speed and acceleration is one of:

the same as said second twisting speed and acceleration, and

different from said second twisting speed and acceleration.

15. The fiber grating fabrication apparatus of claim 11, wherein said third process stage comprises:

a heater for heating a portion of said optical fiber to a predefined process temperature, said process temperature being sufficient to cause said optical fiber to be susceptible to twisting.

16. The fiber grating fabrication apparatus of claim 15, wherein said heater comprises:

a heat source for generating heat;

a conductor for conducting heat generated by said heat source to a predefined area of said heater such that heat is applied to said optical fiber in an heating area only sufficient to enable said optical fiber to be twisted at said area, when said area is heated to said process temperature.

17. The fiber grating fabrication apparatus of claim 16, wherein said heater further comprises:

a temperature control medium for restricting propagation of heat along said optical fiber outside said heating area.

18. The fiber grating fabrication apparatus of claim 17, wherein said temperature control medium comprises at least one of insulation medium and an active cooler.

19. The fiber grating fabrication apparatus of claim 16, further comprising first linear translation means for moving at least one of said first, second and third process stages relative to one another at a first translation speed and acceleration such that said optical fiber is moved through said heater while said optical fiber is being twisted.

20. The fiber grating fabrication apparatus of claim 19, wherein said first linear translation means moves said at least one of said first, second and third process stages relative to one another such that both said first and second ends of said optical fiber are moved at said first translation speed and acceleration.

21. The fiber grating fabrication apparatus of claim 19, wherein said first linear translation means moves said at least one of said first, second and third process stages relative to one another such that a first portion of said optical fiber that has not passed through said heater is moved at said first translation speed and acceleration and a second portion of said optical fiber that has passed through said heater and has been twisted is moved at a second translation speed and acceleration, higher that said first translation speed and

acceleration, thereby reducing a diameter of said second portion of said optical fiber, such that said resulting chiral fiber grating is of a lesser diameter than said optical fiber.

22. The fiber grating fabrication apparatus of claim 19, further comprising a control unit, connected to said first, second, and third process stages, operable to automatically control operation thereof to produce a chiral fiber grating from an optical fiber.

23. The fiber grating fabrication apparatus of claim 19, wherein said control unit is connected to said first linear translation means, and is operable to control:

said first and second twisting direction;

said first twisting speed and acceleration;

said second twisting speed and acceleration;

said process temperature;

said first translation speed and acceleration; and

said second translation speed and acceleration.

24. The fiber grating fabrication apparatus of claim 23, further comprising monitoring means, connected to said control unit, for monitoring

optical characteristics of said chiral fiber grating during operation of said first, second and third process stages to determine whether said produced chiral fiber grating is meeting predetermined fabrication requirements.

25. The fiber grating fabrication apparatus of claim 24, wherein when said monitoring means determines that said chiral fiber grating does not substantially satisfy said predetermined fabrication requirements, said control unit is operable to:

determine which parameter of the group consisting of: said first and second twisting direction, said first and second twisting speed and respective acceleration, said process temperature, and said first and second translation speed and respective acceleration, is causing deviation from said predetermined fabrication requirements, and

change at least one of said parameters until said monitoring means determines that said predetermined fabrication requirements have been substantially satisfied.

26. The fiber grating fabrication apparatus of claim 19, wherein said control unit is operable to selectively control at least one of said first and second twisting speed and respective acceleration and said first and second translation speed and respective acceleration to produce a modified chiral fiber grating selected from a group consisting of:

a chirped chiral fiber grating having a period that varies along said central longitudinal axis.

an apodized chiral fiber grating having a first section, a sequential second section of a constant grating strength, and a sequential third section, wherein said first section comprises increasing grating strength, and said third section comprises decreasing grating strength; and

a distributed chiral twist fiber grating having a first section of a first pitch, a second section of a second pitch, and a third section of said first pitch, wherein said second section comprises a distributed chiral twist of a predetermined angle between said first and said third sections.

27. The fiber grating fabrication apparatus of claim 22, further comprising a feeding unit for feeding a predetermined length of said optical fiber through one of said first and second process stages until said optical fiber is secured at both said first and second process stages.

28. The fiber grating fabrication apparatus of claim 27, wherein said feeding unit further comprises cutting means for cutting said optical fiber after said optical fiber has been secured.

29. The fiber grating fabrication apparatus of claim 27, wherein said feeding unit further comprises a fiber preparation unit for preparing an optical fiber to receive said refractive index modulation.

30. The fiber grating fabrication apparatus of claim 29, wherein said fiber preparation unit further comprises one of:

machining means for inscribing at least one groove in an outer surface of said optical fiber along said central longitudinal axis, wherein when two grooves are inscribed, each of said two grooves is positioned opposite to one another on said outer surface; and

fiber shaping means for shaping said optical fiber into a shaped optical fiber core having a non-circular cross-section with 180 degree cross-sectional symmetry.

31. The fiber grating fabrication apparatus of claim 30, wherein said fiber shaping means comprises a heater for heating said optical fiber and a shaped drawing device for drawing said optical fiber into said shaped optical fiber core.

32. The fiber grating fabrication apparatus of claim 29, wherein said control unit is connected to at least one of said feeding unit, said cutting unit, and said fiber preparation unit, and is operable to control operation thereof.

33. The fiber grating fabrication apparatus of claim 32, wherein said control unit is operable to :

automatically activate said feeding unit to feed another predetermined length of an additional optical fiber through one of said first and second process stages;

activate said cutting means to cut said additional optical fiber after said additional optical fiber has been secured at both said first and second process stages, after said predetermined length of said optical fiber has passed through said first, second and third process stages and has been formed into said chiral fiber grating; and

activate said first, second and third process stages to form an additional chiral fiber grating from said additional optical fiber.

34. The fiber grating fabrication apparatus of claim 24, further comprising adjustment means, connected to said monitoring means, for adjusting optical characteristics of said chiral fiber grating after said fiber grating exits said first, second and third process stages, when said monitoring means determines that said produced chiral fiber grating has not met said predetermined fabrication requirements.

35. The fiber grating fabrication apparatus of claim 34, wherein said adjustment means comprise at least one fiber grating modification device selected from a group consisting of:

secondary twisting means for applying additional twists to said produced chiral fiber grating; and

drawing means for changing a length of said produced chiral fiber grating.

36. The fiber grating fabrication apparatus of claim 22, further comprising an annealing unit for heating, to an annealing temperature, and then slowly cooling said fiber grating after said fiber grating exits said first, second and third process stages to thereby reduce stress in said fiber grating.

37. The fiber grating fabrication apparatus of claim 22, further comprising a cladding application unit for applying, when said fiber grating is formed from an unclad optical fiber, at least one layer of cladding to said fiber grating after said fiber grating exits said first, second and third process stages.

38. The fiber grating fabrication apparatus of claim 22, further comprising a collection unit for collecting and storing at least one fiber grating after each of said at least one fiber grating exits said first, second and third process stages.

39. The fiber grating fabrication apparatus of claim 12, wherein said first direction is the same as said second direction, further comprising:

second linear translation means for moving at least one of said third process stage and both said first and second process stages relative to one another at a third linear translation speed and acceleration, such that a substantial portion of said optical fiber passes through said third process stage

40. The fiber grating fabrication apparatus of claim 39, wherein said third process stage comprises:

a machining unit that inscribes at least one helical groove of a predefined pitch in an outer surface of said optical fiber along said central longitudinal axis, wherein when two helical grooves are inscribed, each of said two grooves is positioned opposite to one another on said outer surface such that a second helical groove of said two grooves is shifted forward from a first helical groove of said two grooves by substantially one half of said predefined pitch.

41. The fiber grating fabrication apparatus of claim 40, further comprising a first process control unit operable to selectively control at least one of said first and second twisting speed and respective acceleration and said third translation speed and acceleration to produce a modified chiral fiber grating selected from a group consisting of:

a chirped chiral fiber grating having a period that varies along said central longitudinal axis;

an apodized chiral fiber grating having a first section, a sequential second section of a constant grating strength, and a sequential third section, wherein said first section comprises increasing grating strength, and said third section comprises decreasing grating strength; and

a distributed chiral twist fiber grating having a first section of a first pitch, a second section of a second pitch, and a third section of said first pitch, wherein said second section comprises a distributed chiral twist of a predetermined angle between said first and said third sections.

42. The fiber grating fabrication apparatus of claim 40, further comprising second monitoring means for monitoring optical characteristics of said chiral fiber grating during operation of said first, second and third process stages to determine whether said produced chiral fiber grating is meeting predetermined fabrication requirements.

43. The fiber grating fabrication apparatus of claim 42, further comprising second adjustment means, connected to said second monitoring means, for adjusting optical characteristics of said chiral fiber grating after said fiber grating exits said first, second and third process stages, when said second monitoring means determines that said produced chiral fiber grating has not met said predetermined fabrication requirements.

44. The fiber grating fabrication apparatus of claim 40, further comprising a second annealing unit for heating, to an annealing temperature, and then slowly cooling said fiber grating after said fiber grating exits said first, second and third process stages.

45. The fiber grating fabrication apparatus of claim 40, further comprising a second cladding application unit for applying, when said fiber grating is formed from an unclad optical fiber, at least one layer of cladding to said fiber grating after said fiber grating exits said first, second and third process stages.

46. The fiber grating fabrication apparatus of claim 40, further comprising a second collection unit for collecting and storing at least one fiber grating after each of said at least one fiber grating exits said first, second and third process stages.

47. The fiber grating fabrication apparatus of claim 39, wherein said third process stage comprises:

a wrapping unit that wraps at least one fiber element composed of a different dielectric material from said optical fiber and having a diameter less than said optical fiber, in a helical pattern of a second predefined pitch around said outer surface of said optical fiber along said central longitudinal axis, wherein when two fiber elements are wrapped, a second helical pattern formed

by the second of said two fiber elements is shifted forward from a first helical pattern of the first of said two fiber elements by substantially one half of said second predefined pitch.

48. The fiber grating fabrication apparatus of claim 47, further comprising a second process control unit operable to selectively control at least one of said first and second twisting speed and respective acceleration and said third translation speed and acceleration to produce a modified chiral fiber grating selected from a group consisting of:

a chirped chiral fiber grating having a period that varies along said central longitudinal axis;

an apodized chiral fiber grating having a first section, a sequential second section of a constant grating strength, and a sequential third section, wherein said first section comprises increasing grating strength, and said third section comprises decreasing grating strength; and

a distributed chiral twist fiber grating having a first section of a first pitch, a second section of a second pitch, and a third section of said first pitch, wherein said second section comprises a distributed chiral twist of a predetermined angle between said first and said third sections.

49. The fiber grating fabrication apparatus of claim 47, further comprising third monitoring means for monitoring optical characteristics of said chiral fiber grating during operation of said first, second and third process stages

to determine whether said produced chiral fiber grating is meeting predetermined fabrication requirements.

50. The fiber grating fabrication apparatus of claim 49, further comprising third adjustment means, connected to said third monitoring means, for adjusting optical characteristics of said chiral fiber grating after said fiber grating exits said first, second and third process stages, when said third monitoring means determines that said produced chiral fiber grating has not met said predetermined fabrication requirements.

51. The fiber grating fabrication apparatus of claim 47, further comprising a third annealing unit for heating, to an annealing temperature, and then slowly cooling said fiber grating after said fiber grating exits said first, second and third process stages.

52. The fiber grating fabrication apparatus of claim 47, further comprising a third cladding application unit for applying, when said fiber grating is formed from an unclad optical fiber, at least one layer of cladding to said fiber grating after said fiber grating exits said first, second and third process stages.

53. The fiber grating fabrication apparatus of claim 47, further comprising a third collection unit for collecting and storing at least one fiber

grating after each of said at least one fiber grating exits said first, second and third process stages.

54. A method for fabricating a fiber grating structure from an optical fiber having a central longitudinal axis, comprising the step of :

(a) imposing refractive index modulation along the central longitudinal axis of said optical fiber in one of a first and second configuration, wherein in said first configuration said optical fiber is formed into a chiral structure having a first pitch and a period, wherein said first pitch is twice said period, and wherein in said second configuration said optical fiber is formed into a chiral structure having a second pitch and a period, wherein said second pitch is substantially equal to said period.

55. The fabrication method of claim 54, wherein the optical fiber comprises a first end and a second end, and wherein said step (a) comprises the steps of:

(b) retaining said first end of said optical fiber;

(c) retaining said second end of said optical fiber;

(d) imposing said refractive index modulation in one of said first and second configurations on said optical fiber, between said first end and said second end, to form said optical fiber into a chiral fiber grating.